DOCUMENT RESUME

ED 109 718 CS 501 088

AUTHOR Stech, Ernest L.
TITLE Structural and Process Models of Human Communication Systems.
PUB DATE Jan 75
NOTE 47p.; Paper presented at the 1975 Purdue Post Doctorate Honors Seminar

EDRS PRICE MF-$0.76 HC-$1.95 PLUS POSTAGE
DESCRIPTORS Communication (Thought Transfer); Higher Education; Human Relations; *Literature Reviews; *Models; *Organizational Communication; Organizational Theories; *Research Methodology; *Systems Analysis

ABSTRACT

It is argued that the structural and process models of human communication systems can be derived from the same data, and that communication systems can be described in terms of certain basic parameters; these parameters, in turn, provide a taxonomy of system types. The applicable empirical research data is reviewed to make statements about the existing knowledge concerning the structural and process facets of systems in which human beings are the components. In summary, the research literature showed that the two most commonly used models for empirical studies are the component structural model (who communicates with whom) and the component state process model (what is said after what). Matrix methods, uncertainty statistics, and graph theory methods have been employed sparingly in the analysis of communication systems data. The author concludes that communication systems, however, are organized or structured in at least three different senses, as networks of components, as sequences of components, and as sequences of component states. (RB)

****
* Documents acquired by ERIC include many informal unpublished *
* materials not available from other sources. ERIC makes every effort *
* to obtain the best copy available. nevertheless, items of marginal *
* reproducibility are often encountered and this affects the quality *
* of the microfiche and hardcopy reproductions ERIC makes available *
* via the ERIC Document Reproduction Service (EDRS). EDRS is not *
* responsible for the quality of the original document. Reproductions *
* supplied by EDRS are the best that can be made from the original. *
****

U S DEPARTMENT OF HEALTH
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION
THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

ED109718

PAPER A

STRUCTURAL AND PROCESS MODELS OF HUMAN COMMUNICATION SYSTEMS

Ernest L. Stech
Communication Arts and Sciences
Western Michigan University
Kalamazoo, Michigan
49007

PERMISSION TO REPRODUCE THIS COPYRIGHTED MATERIAL HAS BEEN GRANTED BY

Ernest L. Stech

TO ERIC AND ORGANIZATIONS OPERATING UNDER AGREEMENTS WITH THE NATIONAL INSTITUTE OF EDUCATION. FURTHER REPRODUCTION OUTSIDE THE ERIC SYSTEM REQUIRES PERMISSION OF THE COPYRIGHT OWNER

January 1975

CS 501 088

A-1

STRUCTURAL AND PROCESS MODELS OF HUMAN COMMUNICATION SYSTEMS

The purpose of this paper is to show, first, that the structural and process models of human communication systems can be derived from the same data and that neither model, alone, is a satisfactory description of a communication system. A second purpose is to show that communication systems can be described in terms of certain basic parameters, and these parameters in turn provide a taxonomy of system types. Finally, it is my intent to review the applicable empirical research data to make statements about our knowledge of both the structural and process facets of systems in which human beings are the components.

General systems theory expositions have suffered from a common fault. They operate at levels of abstraction and generality which leave the reader perplexed about what they mean at the practical and pragmatic level of day-to-day communication activities. The authors typically posit sets of relationships of the form:

$$S = f(G,H,I,J,K,L)$$

where S is a parameter or characteristic of state of the communication system and G,H,I,J,K, and L are variables which affect that parameter, characteristic, or state. The next step is to point out that the function, f, may be nonlinear, complex, or in some other way difficult to specify at the moment. A few of the expositors have gone beyond this level of system specification.

Recently, Weick (1974) has called for the development of middle range theories of social systems. Weick argues that systems theorizing has been on such a high level of abstraction that frequently the statements made are not falsifiable. Early in his article, Weick points out two problems which have not been faced by systems theorists and systems analysts. The first is that patterns automatically imply the existence of systems. That assumption cannot be made without demonstration. The second notion is that "a system is a system is a system," when in fact there are tightly coupled and loosely coupled systems, systems of high organization and of low organization.

In this paper, I shall address myself primarily to the question of whether or not patterns exist in human communication systems and only indirectly with the question of whether or not systems exist which produce the patterns. The evidence on the first question is more directly available and easier to interpret. The second question requires more inference and less direct evidence.

A 2

BASIC MODELS OF COMMUNICATION

In the formulation of information theory by Shannon and Weaver (1949), a model of a communication was postulated which included a message source, a channel over which the message was sent, and a message receiver. The elements of the model were picked up by Berlo (1963) in his classic text on the process of communication. Berlo listed the following major elements in a model of human communication: the communication source, the encoder, the message, the channel, the decoder, and the communication receiver. The Shannon and Weaver and Berlo models involve two communication units, sender and receiver, connected by a channel. Flow is one directional, from source to receiver.

This very elementary form of model, useful in assessing channel capacity and effects of noise in electronic communication systems, provides a beginning point for building more complex and valid models. Three basic elements of a communication system will be assumed here: components, channels, and messages. A component is defined as an agent, being, or object which can take on various states, and a channel is a link by which energy can be transferred from one component to another. A message is a temporal event the full definition of which must await some additional description of the communication system.

Units can be in one of two mutually exclusive energy states: active or passive. In the passive state, the unit is incapable of sending or receiving messages. The active state can be further subdivided into two substates: sending and receiving, which are mutually exclusive. In the passive state, the unit is incapable of sending or receiving messages. For a two unit system the possible combinations of states are shown in Figure 1.

Certain system formation rules can be stipulated at this point:

1. If one unit in a two unit system is in a passive state, no communication system exists since no energy transfer can take place.

2. If both units are sending, the result is babble.

3. If both units are receiving, the result is silence.

4. If one unit is sending and the other receiving, the result is energy transfer and communication.

Thus, a preliminary definition of communication results from the model and stipulates that communication occurs when one unit is sending and the other receiving and there is resulting energy transfer. Energy transfer does not occur in mutual sending or mutual receiving.

The model, up to this point, is a structural version of communication. Since two objects cannot occupy the same point in space, the two unit model implies that the energy transfer occurs across space. Time must also be taken into account. At any given point in time, a unit is either in a passive or active state and if in an active state is either in a sending or receiving state. Observation over time would show that the unit changes from passive to active or in reverse and from sending to receiving or in reverse. Thus, we can plot state changes over time.

If a unit changes from passive to active, the process is termed activation. The reverse process is called passivation. Once a unit is in the active state, it alternates between sending and receiving modes of operations. Figure 2 illustrates the four possible states of the system over time. If one unit begins sending while the other unit is still sending, the result is called an "interruption" and the system state is babble. If one unit stops sending and the other unit does not begin immediately (latency or lag of response occurs), the result is system silence. If one unit is sending and the other unit is receiving, and the sending unit changes to listening and the listening unit changes to sending, the result is a shift in the direction of energy transfer from one unit to the other. This shift in energy transfer helps to define a message in the communication system. The definition is as follows:

5. A message occurs when the energy exchange direction has shifted twice in a two unit communication system.

This operational and behavioral definition of a message implies that a message occurs when one unit shifts from the listening mode to the sending mode, persists in the sending mode for some finite period of time, and then reverts to the listening mode.

STRUCTURAL AND PROCESS MODELS OF COMMUNICATION SYSTEMS

A communication system, for the purposes of this exposition then, consists of components which can be in one of three states: sending, receiving, or passive. The state of a communication system can be expressed in the form of a matrix such as that shown in Figure 3. The horizontal axis represents potential sending units, and the vertical axis lists potential receiving units. To indicate a linkage between two components, the cell representing the row of the sender and the column of the receiver is filled in. Every filled-in cell represents a communication linkage between two units in the system. If an entire row is filled in, the system is in a state in which one component is sending and all the others are receiving. If a column is filled in, the system is in a state in

which one component is receiving messages simultaneously from all the other components.

A matrix of the type shown in Figure 3 represents the state of the communication system at an instant in time. It is a snapshot of the system. A series of such smapshots in sequence would appear as shown in Figure 4. The system state changes at each new time period shown in Figure 4, but changes are not necessary. In time sampling where a system state matrix is taken at fixed intervals, the system may be in the same state on two or more consecutive times. Sometimes systems are sampled only when a new state occurs, and in such a procedure, the system state matrices obviously change with each new sampling point.

A variety of different forms of analysis can be performed on the sequence of system state matrices shown in Figure 4. One common procedure is to sum across time all of the linkages between components which results in a who-talked-to-whom matrix of the type shown in Figure 5. In effect, this is the kind of matrix generated by a sociometric questionnaire or questions of the form "to whom do you send messages?" "from whom do you receive messages?" or "with whom do you communicate?" The respondent attempts to sum across time via memory and provide the investigator with a report of whom-to-whom contacts.

A slightly more sophisticated version of the same matrix is shown in Figure 6 where a frequency count of number of linkages is shown. Not only is data available on who-talks-with-whom but also how frequently they contact one another and with directionality. A difference between the distribution of frequency of sending and frequency of receiving represents some kind of patterning of the contact. It implies that there is a network with directionality in the system. The frequency matrix can be modified to show only contacts between components without regard to direction, with the result shown in Figure 7. In this matrix the row and column totals are the same since directionaltiy has been eliminated from the data.

Another way of showing the same kind of data is by means of a graph or network diagram as drawn in Figure 8. Each component is represented by a circle, and the contacts between components are represented by lines with direction indicated with arrows. Often the network is drawn as shown in Figure 9 where the clustering of the components according to frequency and directionality of contact is shown graphically. Sociometric networks are most frequently shown in this format.

From the basic data on system states at specified times over a time period, then, the following kinds of reduced data can be obtained:

(1) who has talked to whom and who has listened to whom;

(2) who has talked how frequently to whom and who has received messages how frequently from whom;

(3) between which component have linkages occurred without regard to direction;

(4) how frequently have linkages occurred between components without regard to direction;

(5) a graph showing linkages and directions;

(6) a graph showing linkages without regard to directionality;

Thus, the spatial structure of the communication system can be described by adding up the contacts between components, together with the direction of contact if desired. The results are structural models built up from data collected over some finite period of time and with the data summed across time. Examples of such structural models and their implications for communication systems will be discussed in more detail later in this report.

An entirely different kind of model results from the analysis of the data from time sample to time sample rather than through summing. Figure 10 shows the component and system states at five different times along a time line format. The state of the system at any given time can be given by the three numbers at the bottom of the chart which show the number of components sending, receiving, and passive at each point in time. By summing across the time line for each component, the number of times the component sent, received, or was passive can be totalled.

A matrix can be generated showing the transitions from one component state to another as shown in Figure 11. This information summarizes the state changes for all components in the system. It is possible, of course, to develop a state change matrix of this type for each component separately if there is enough data in the original sample.

The matrix of Figure 11 should reveal, in a crude way, the existence of patterns of state shift over time and in this sense represents a process model of the system. A more revealing format is the relative frequency matrix shown in Figure 12. This matrix illustrates the relative proportion of total state changes occurring in each cell of the matrix, and it is suitable for the calculation of information theory statistics. Another way of operating on the basic matrix is to show transitional probabilities as illustrated in Figure 13. In this type of matrix, the rows all sum to 1.00,

and the relative frequencies show the probability of each of the states following the state represented by that row. Finally, this transitional probability matrix can be presented in state change graph form as shown in Figure 14 where the states are shown with circles, and the lines and arrows show the probability of shifting to another state.

The basic data can be transformed, then, into the following reduced formats:

(1) relative frequency of total system states with each system state represented by the proportion of components sending, receiving, and passive;

(2) relative occurrence of each component state for each component (how frequently did each component send, receive, or remain passive);

(3) state changes and relative frequencies of state changes summed across all components;

(4) state changes and relative frequency of state changes summed for each component separately;

(5) transitional probabilities for each state summed across all components; and

(6) transitional probabilities for each state for each component in the system.

All of these reduced data formats represent process models of the system. Rather than dealing with relationships in space and summed across time, they deal with relationships from one time to the next succeeding point in time for the systems components taken together or separately.

In summary, a record can be kept of the state of each component of a communication system at specified points in time. The record can be converted into two kinds of formats. In one form, the data show the relationships among the components or system states summed over time. This is the "who-to-whom" (or "what-to-what") kind of information about the system. The other format shows the temporal or sequential relationships between system states or components. This is the "what -follows-what" or "who-follows-whom" kind of information about the system.

PARAMETERS OF COMMUNICATION SYSTEMS

Our traditional way of classifying communication situations has not been very satisfactory. We distinguish between intrapersonal, interpersonal, small group, public, and mass communication, the underlying parameter being the size of the system. Yet organizational communication involves large number of people engaged in interpersonal, public, and mass communication activities. And of course, the dividing points, for example between interpersonal and small group communication, are quite arbitrary. This kind of taxonomy has utility in setting up college courses and drawing rough distinctions between different kinds of communication situations, but it is far from satisfactory.

Based upon the considerations discussed thus far in this paper, a communication system can be specified and classified from eight basic parameters:

(1) number of components

(2) number of possible states for each component

(3) length of time the system has had active components

(4) physical proximity of the components

(5) degree to which there are energy linkages between components (who communicates to whom?)

(6) degree to which there are temporal relationships between components (who communicates after whom?)

(7) degree to which there are energy linkages between component states (what kinds of things are going on simultaneously?)

(8) degree to which there are temporal relationships between component states (what kinds of things occur after other things?)

Description of these eight characteristics of a communication system will provide a useful base for the classification of the system into a taxonomic scheme and also allow the investigator to interpret findings about the components, messages, and linkages.

The number of components in a system determines the size of the system. This parameter carries over one criterion from our traditional approach. It is important to know if the system consists of two, twenty, two hundred, or two thousand components. Yet the

sheer size of the system does not provide a very adequate picture of the system characteristics. For example, it is possible to have two thousand people in an auditorium acting as an audience or to have two thousand people sitting in an office building acting as a business organization. Obviously, more than size must be taken into account.

Possible component states give a different kind of clue to the system. In effect, the potential number of component states defines the complexity of the system, or at least the complexity of the model used to describe the system. Each component may be in one of two states, sending or receiving for example, or the components may take up to twelve states as in Bales' interaction process analysis category system. Some communication systems severely restrict the number of possible states of components, take for example the audience listening to a speaker. Audience members are supposed to take only one state, that of passive listening, unless there is a question and answer period. In the organizational setting, on the other hand, each person can take on at least the sending, receiving, or passive states and within the sending and receiving states can be in a large variety of substates.

Figure 15 illustrates the possible combinations of systems size and component state complexity with some illustrative examples included. A small system such as a dyad may have highly restricted number of component states such as occurs when two formal roles are played out in a social setting. Conversely, two persons may take on a wide variety of states in intimate interpersonal relationships. A person may become angry, affectionate, passive, verbose, attentive, assertive, and so on. The same person in a role, such as that of counselor, would tend to restrict states to the attentive, questioning, and supportive.

There may be limitations on component states in large systems, for example the restrictions on audience members in speaker-audience situations. In crowds, mobs, and demonstrations on the other hand, each component is allowed a much wider range of possible states.

As the number of components and number of potential component states increase, the absolute uncertainty (information, entropy) of the communication system increases. There are more possible choices at any given point in time. It may be, therefore, that there is some optimum balance of system size and number of component states that is desirable, acceptable, or normative for human beings in general. As system size increases, the number of possible states decreases and vice versa. Small systems can tolerate large repertoires of component states whereas large systems tend to restrict component states. These are hypotheses, at this point in time, and need verification through research.

The time period for which the system exists and the geographical distribution of components must also be taken into account in des-

cribing the system characteristics. Time is required for message sending. Each message takes a finite period of time. Therefore, as the number of components increases and the number of potential component states increase, the total time required for message sending and receiving must increase as well. If there are time limitations on interaction, the number of components or component states must be restricted. Similarly, each component in a communication system takes up a finite amount of space. As the number of components increase, the total space taken up by the system increases.

There is yet another relationship between space and time characteristics of communication systems. If all the components are in close proximity, simultaneous sending will result in babble. There will be "noise," in a loose sense, in the environment. If the components are separated, on the other hand, there can be simultaneous sending by several components without interference. Thus, more messages can be sent per unit time in a physically separated component system but the messages can only be received by a portion of the total available components.

System size, component states, available time, and component location interact, then, to define the basic communication system. A system designer can explore tradeoffs between these parameters, and the systems analyst can describe their relationships for any given communication system.

The next step, in accordance with the discussion of the preceding section of this paper, is to define the degree to which components or component states are related to one another in time or in space. Structural models result in a description of the interconnectedness of components or component states. In its most elementary form, the measure is of the number of components which send or receive from other components as a proportion of the total components in the system. The more sophisticated measures use information theory statistics which define the relative structure due to unequal distribution of acts and due to the existence of directional pathways in the network. Graphical methods can be used to describe the paths and their characteristics, that is, whether they are for example, serial or loop. Process models result in a description of the temporal sequencing of components or component states. The measures tend to show the degree to which an observer can predict which component will send next or what kind of message will be sent based upon the frequency of occurrence of message sending in the past and also on the syntactical relationships which tend to result in patterns of message sending over time.

The process and structure model parameters result in a four dimensional taxonomic system in which the following criteria are used for classification (see Figure 16):

(1) the degree of constraint, high or low, in the network of connections between components, the component structural model;

(2) the degree of constraint, high or low, in the process of which component sends after which other components, the component process model;

(3) the degree of constraint, high or low, in the network of connections between component states, the component state structural model; and

(4) the degree of constraint, high or low, in the process of which component state follows which other component states, the component state process model.

As will be shown below, research has tended to focus on the component structural model (who speaks to whom) and the component state process model (what is said after what).

Using these parameters, a communication system could be classified, for example, as having a high degree of constraint in the component structure and process models and also high constraint in the component state structure and process models. Ritual in a church or fraternal organization is typical of this high constraint situation. It is easy to predict who will speak to whom, who will speak next, what will be said or done while something else is going on, and what will be said next. The rites specify the networks and sequences. Another kind of situation is characterized as having low constraint in the component structural and process models, low constraint in the component state structural model, and high constraint in the component state process model. This means that what is said next is highly predictable but who says it, what else is going on, and who will talk next are not predictable. Small groups composed of people who do not know each other well but are forced to use a fixed problem solving procedure exhibit this kind of characteristic.

In summary, communication systems can be classified using two different kinds of criteria. System size, state complexity, schedule, and geography can be observed and reported. Secondly, the degree to which the components and component states are interconnected or predictable through space and time can be recorded and quantified. The next question is to examine the methods available for analytical treatment and then to review the empirical research to discover the degree to which investigations have dealt with these system parameters.

ANALYTICAL METHODS OF DEALING WITH THE MODELS

There are four basic analytical tools available and commonly used with the communication system models described previously:

(1) Markov process methods,

(2) matrix algebra,

(3) graph theory, and

(4) information theory.

Standard texts are available which describe the various techniques in detail. Markov processes and matrix algebra methods are presented for the layman in Bartos (1967). A standard text on graph theory is that by Benzad and Chartrand (1971). Garner's work (1962) on uncertainty and structure as psychological concepts is the standard text on information theory measures.

Matrix algebra is a basic tool for Markov chain analysis, described in the paragraphs below, and for the analysis of multi-link paths or multi-step sequences in graph theory. If a matrix contains "1's" to indicate the existence of a link between component or a step between events and "0's" to show lack of linkage, the result is a matrix showing the one-link connections or one-step sequences in a communication system. Squaring such a matrix shows the two-link or two-step connections. Raising to the power of three will provide the three-link or three-step connections, and so on for higher powers. Festinger (1949) has described this use of matrix algebra for finding multi-step connections in sociometric networks and also for the discovery of cliques in such networks. The same basic method can be applied to time ordered data to show multi-step sequences. (Matrix multiplication is commonly available on computers and data processing systems which have the BASIC programming language available.)

Special methods have been developed for analyzing specific features of communication nets using graph theory and matrix algebra techniques. In addition to Festinger's work, Harary and Ross have published material on clique detection (1957) and determination of complete cycles in a network (1954). They have also defined persons they term "strengthening and weakening" members of groups (1959). Harary has also devised a method for dealing with status in hierarchical networks (1959). Rapoport and Rebhun (1952) developed a model for the dissemination of a message in a random probabilistic network.

Markov chain analysis is a readily available tool for assessing the probabilistic chaining of events. In an independent trial

process, each event is independent of any preceding events, which is the assumption usually made in sampling theory. In a Markov process, the transition probabilities from one event to the next are greater than zero so that they are not independent. The probabilities may change from trial to trial in a Markov process. The Markov chain is a more restrictive and commonly used model since it represents the case in which the transition probabilities remain constant from trial to trial. The Markov chain is also termed a finite Markov process.

The method relies upon the use of a square matrix of transition probabilities which show, in each cell, the probability of one event or state succeeding another event or state. The rows sum to 1.00. When such a matrix is multiplied by itself several times over, that is, it is raised to some power, the result is a convergence of the probabilities in the cells on an equilibrium process. If the original matrix represented the equilibrium process, then raising the matrix to a power does not change the values in the cells. On the other hand, a matrix which does not represent an equilibrium condition will show changes in the cell values. This feature of the Markov chain analysis procedure has two possible uses. In one case, a process may be sampled early in its history, the transition probability matrix generated, and the equilibrium process computed. This predicted equilibrium process can then be compared to actual data obtained later in the history of the system or over the entire life span of the system. If the predicted values are close to the obtained values, the system exhibits equilibrium over time.

The other potential use is to take a matrix of transition probabilities generated from a long term large sample of event sequences and then raise the matrix to a power of 5 or more. If there is little shift in the cell entries, the process described by the matrix is probably in an equilibrium process. If there is a shift, the process represented by the matrix is not an equilibrium process which means that the transition probabilities shift from time period to time period as a result of externally impinging force.

It seems possible to speculate that a system which exhibits equilibrium in the Markov chain sense of the term is a closed system in which state transition probabilities between the elements in the system are a sufficient description of its process nature. Systems in which the transitional probability matrix is not the equilibrium process matrix are open systems subject to forces beyond the internal structure of the components or elements.

At least one mode of group communication has been devised using the Markov chain method (Karlsson, 1955). The model attempted to predict how behavior would spread among the members of a face to face group assuming an initial state and certain transition probabilities. There was no empirical test of the model. Most of

the work with Markov chain models has been in the field of two-person learning theory paradigms (see Berger, et. al., 1962).

Graph theory provides another kind of analytical tool for working with networks or chains of events. A graph consists of points connected by lines, the technical terms for which are vertices and edges, respectively. There are several characteristics of different kinds of graphs which can be used to diagram communication networks. Some graphs are directional and are termed digraphs. They show the direction of the flow of communication between units. A loop graph includes the possibility of a component being connected to itself.

One of the parameters of a graph is distance, that is, the sum total of the number of different possible paths connecting every unit with every other unit. This is the current formal treatment of the problem of centrality introduced by Bavelas (1948) in his network studies. The distance of a graph can be calculated for various possible connections between points.

The unique character of certain vertices or points in a graph can be specified with graph theory. Ross and Harary (1955) have defined a liaison person in a network as one who occupies an articulation point in a graph, the articulation point being a vertex which, if removed, would result in a disconnected graph. The removal of an articulation point results in two separate disconnected subgraphs. A graph can be analyzed into subgraphs, and at least one kind of subgraph in a sociometric network is called a clique.

Thus, graph theory provides a way of describing communication networks in a systematic and formal way. Graph theory and matrix algebra are linked together in mathematics in the form of the adjacency matrix of a graph (Behzad and Chartrand, 1971, Chapter 4). Matrix multiplication provides a way of analyzing paths in a network using the adjacency matrix, as noted earlier in this paper.

The uncertainty statistic, U, is the social science equivalent of the information theory statistic, H. Garner (1962) pioneered the development of the statistical procedures in estimating uncertainty. The basic measure is that of uncertainty which corresponds roughly to the number of discrete, mutually exclusive possibilities or choices available to an individual. Uncertainty can be expressed in bits just as in information theory. A bit is one binary choice. Relative uncertainty is the actual uncertainty of a distribution of events or objects into nominal categories versus the maximum uncertainty available due to the categories and may vary from 0 to 100%. Relative structure is expressed as relative uncertainty subtracted from 100% and represents a measure of the degree of constraint in a choice situation. A relative structure of 100% would indicate no choice available; a relative structure of 0%

would indicate perfectly equal choice among whatever alternatives are available in the situation. The absolute value of the uncertainty in case of 0% relative structure has to be presented in terms of the number of bits. The absolute value of the uncertainty in case of 100% relative structure is zero bits.

Uncertainty or structure values can also be calculated for bivariate distributions. Each of the two distributions will have an uncertainty value. In addition, there will be a joint uncertainty, very similar to the notion of covariance in parametric statistics. If the matrix represents preceding and succeeding units, the joint uncertainty represents the degree to which there is lack of sequencing among the units. If there is low joint uncertainty and high joint structure, there probably exist sequences among the units.

If the matrix simply represents connections rather than sequential states, the joint uncertainty describes the degree to which there is lack of pathways, that is, directional movement, through the network. High relative joint structure would indicate the existence of directional paths in the network.

Unfortunately, the uncertainty statistic has no associated significance level. If information is needed on the probability that a distribution, either a single distribution or a joint distribution, differs from chance expectation, the Chi square statistic must be employed. In most cases this is no problem. However, there are cases in which the uncertainty statistic can be calculated but Chi square cannot, principally when cell values drop below five in a matrix.

The four methods discussed here - matrix algebra, Markov chains, graph theory, and information theory - provide some useful data about communication systems. The kinds of measures are summarized in Table 1. There is neither the space nor time to discuss at greater length here the relationships between the various measures. There are, for example, relationships between the number of steps of iteration required to get to an equilibrium process matrix in a Markov chain analysis and the decrease in additional information which results as more units are added to a sequence of message units. It is sufficient to note here that the methods represent different ways of looking at the same data.

A 15

TABLE 1
FORMAL METHODS AND TYPICAL MEASURES
OF STRUCTURAL AND PROCESS MODELS

Formal Method	Typical Measures	Type of Model
Graph theory and matrix algebra	Distance in a network	Structural
	Centrality of components	Structural
	Single and multi-link pathways	Structural
	Cycles	Structural
	Cliques	Structural
Markov processes and Markov chains	Equilibrium process	Process
	Iterations to achieve an equilibrium process	Process
	Single and multi-step sequences	Process
	Loops	Process
Uncertainty statistic	Absolute and relative distributional uncertainty for a variable	Both
	Absolute and relative distributional uncertainty for a bivariate distribution	Both
	Absolute and relative sequential uncertainty (joint uncertainty) for a bivariate distribution	Both
	Absolute and relative distributional and sequential uncertainty for multivariate distributions	Both

A 16

EMPIRICAL RESEARCH ON COMMUNICATION SYSTEMS USING STRUCTURAL AND PROCESS MODELS

Some empirical data has been collected on communication systems using the various system models described in this paper. The most common study deals with the small group, usually of three to seven or eight persons. Group members are usually college students who have not previously met working on a task assigned by the experimenter. A few studies have been performed on intact groups or on organizations which have prior history and consist of adults.

The first attempt to describe social collectivities with network models was by Moreno (1941) who devised the sociometric method. The technique involved having people write down the people with whom they would prefer to work, play, or communicate. A person may be allowed to write down as many names as possible or may be restricted to three or four names. The result is a matrix of choices. In diagramming the choice network, Moreno was able to identify cliques, isolates, and overchosen members of real groups of delinquent girls. Subsequently, Festinger, Shachter, and Back (1955) showed that the sociograms of a veterans housing unit could be analyzed with matrix algebra to find cliques and pathways.

The problem with sociometric choice networks is that they represent preferences for future contact or communication as opposed to a description of past actual encounter or communication with other persons. A person might choose another individual with whom he or she has had no prior contact. Thus, the sociometric nets reported in the literature do not provide a very useful measure of actual communication networks. Data is needed in which the respondent provides information on which other people have communicated with him or her.

Weiss and Jacobson (1955) analyzed a governmental agency by getting a network of contacts between persons in the unit. They developed a 196x196 matrix and analyzed the choice patterns through matrix multiplication and were able to differentiate work groups and liaison persons in the network. This is the only study of which I am aware which reports the results of a survey of communicative contacts between persons in a real organization as opposed to sociometric preferences.

One other well known form of network data was obtained on the pattern of who-speaks-to-whom in small discussion groups (Bales, Strodtbeck, Mills, and Roseborough, 1951). The relative participation of each person and the direction of each comment, including a category of comments directed "to the group," was recorded and plotted. No attempt was made to analyze the resulting matrix of communicative connections.

The final source of network data is that of the studies resulting from Bavelas' work (1948) on restricted communication channels between persons working on a task. This type of study requires the experimenter to arbitrarily allow certain channels to exist and others to be closed off between participants. Circle, wheel, chain, and common connection networks are created and then compared for relative efficiency or effectiveness. Such studies provide us with data on idealized types of communication networks but obviously do not provide insight into the shape or structure of networks in real social groups.

Generally, the communication network research has employed a component structural model in which the linkages between persons are described, either in matrix or graph form. No effort has been made in the past to describe the degree to which the communication networks represent constraint on message sending. Analytical procedures have tended to concentrate on graph and matrix analysis of paths and clustering of components.

Stech (1975b) has begun the process of calculating the relative structure values for some idealized networks and some real networks as reported in the literature or generated in college classrooms. These calculations, in very preliminary form, have shown a rather small range of distributional structure values and some fairly high values for relative sequential or pathway structure. More of this kind of work is needed to provide a more complete picture of the relative degree or organization in component networks.

The available data do allow the formulation of some preliminary propositions about communication system structure:

> Proposition 1: Components in communication systems are connected in nonrandom networks.
>
> Proposition 1.1: There is inequality in terms of the number of connections components have with other components in the system. (Centrality, peripherality.)
>
> Proposition 1.2: There are consistencies in which components communicate with other components in the system. (Pathways, cliques, seriality.)

These findings seem to hold for both small group interaction and social collectivities in dispersed geographic formats and for both formal and informal organizational schemes.

In effect, these propositions stipulate that communication systems are not randomly connected but involve structural patterns. One kind of pattern is distributional in nature because some people communicate with a lot of other people and some communicate

with very few. Therefore, if you were going to predict the person with whom someone was communicating, the best bet would be the person who communicates with the largest number of other persons. Secondly, if you knew who was talking or who was listening, your next best basis for prediction would be the persons or set of persons with whom that individual had communicated in the past. The degree to which some people talk more than others and the degree to which persons are connected in serial paths or cliques represents a measure of the degree of organization of the communication system from a component structural standpoint.

The principal problem here is to continue the process of calculating relative structure values for both idealized and actual communication systems. The procedure is relatively straightforward, and a large amount of published data exists on which to perform the operations. Some additional data may be needed to provide a wide scope of type of system.

In a fashion analogous to that for component networks, one of the ways in which component sequencing, that is, who speaks after whom, can be predicted is from unequal frequency of participation. If one person talks all the time, quite obviously it is a fairly safe bet that he or she will be talking whenever you tune in on the group. The data from Bales (1955) on the inequality of participation rates supports the notion that this kind of constraint exists in group interaction. I have not yet calculated the relative degree of distributional structure, using the uncertainty statistic, for Bales data, but this is in process.

There is no published data on the question of who-speaks-after-whom in communication systems. Stech (1974) has examined two kinds of patterns in groups of three and four members. Transcripts were analyzed for relative distributional and sequential structure in the processes by which people succeeded one anotner as senders and by which message units were succeeded by other message units. In general, the findings for five three-member groups and five four-member groups was that the component succession process was quite highly structured in terms of distribution but showed almost no structure when viewed as a succession of speakers. In other words, some people consistently spoke more than others, but when the data were corrected for frequency of occurrence, there was no discernible pattern among who followed whom. The three person groups showed more distributional and sequential constraint than the four-member groups. When Chi square was computed on the same data, it was found that one three-person group showed a tendency to sequence among persons. The other nine groups showed random sequencing. Conversely, all of the ten groups showed nonrandom, highly structured sequences of message units. The degree of structure was roughly double for the message sequences when compared to the member sequences.

On the other side of the coin, I have been engaged in an analysis of the published Watergate affair transcripts. These data show a strong tendency for the participants, Nixon, Haldeman, Erlichman, Dean, Ziegler, and Mitchell, to exhibit sequencing patterns. The quantitative estimates of the degree of sequential structure are not yet available, but the patterns of sequencing are quite evident. When three persons are present (Nixon, Haldeman, Erlichman or Nixon, Dean, Haldeman), the president is followed with relatively equal frequency by either of the other two participants, but each of the other people is consistently followed by the president. In effect, the president conducted dialogue with one person and then switched to dialogue with the other person. Trialogue did not occur very frequently at all. Preliminary inspection also showed that the dialogue sequences tend to persist for fairly long segments of the transcripts, suggesting that there are fairly high order constraint systems in the information theory sense.

A recent innovation in the social psychology literature treats this same problem. Duncan (1972) studied the problem of speaking turns and who gets the next turn in small groups. More recently, Burke (1974) has extended the work to participation rate and leadership in small groups. The specific problem investigated in the Burke study revolved around the issue of how the next speaker was designated by the speaker who had the floor in small group discussion. In general, the findings suggested that the turn-taking phenomenon was highly dependent on who had talked the most. Apparently, consistent patterns of who would follow whom were not found.

Jaffe and Feldstein (1970) have performed some pioneering work on the succession of speaking and silence states in both monolgue and dialogue following on the original work of Chapple (Chapple, 1939 and Chapple and Arensberg, 1940). The Jaffe and Feldstein work is important in the present context because it indicates that there are stable equilibrium processes in speaker switching over time. Additional work is required, however, before we can accept this finding as being very general. Inspection of the White House transcripts showed, for example, that stability probably did not exist in the conversations where three persons were present. Who-spoke-next was partially a function of the prior history of the conversation.

These rather sparse data allow the formulation, on a very tentative basis, of some propositions about component sequencing.

> Proposition 2: Persons in communication systems show nonrandom patterns of who communicates after whom.

Proposition 2.1: There is inequality in the number of times a person talks (or the amount of time spent talking) in communication systems.

Proposition 2.2: The degree to which components in the systen are sequenced in their sending can vary from zero to fairly high levels.

Proposition 2.3: There is a shift over time in the degree of component sequencing in communication systems.

As noted above, these propositions are offered very tentatively at this time and need a large amount of additional support before they are accepted. Hopefully, some day we will have available enough data to make statements about the distribution of degree of structure in various kinds of social situations.

The propositions and their supporting findings suggest, then, that we can predict who will speak next primarily because some people talk more than others. Our best bet on who will speak next is always the person who has spoken the most in the past. In some systems, it may also be possible to predict who will speak next because some people consistently speak after others. It seems likely, but is as yet unproved, that the amount a person speaks and who speaks next can very over the history of a communication system so that we cannot assume stability over time.

Additional research needed on component process models includes the following, some of which is underway:

(1) Analysis of the participation of three, four, and more persons in small group settings needs to be recorded and analyzed using the interaction chronograph method in order to assess the degree of predictability of sequencing in larger groups.

(2) Group task and group roles variables need to be examined, particularly the relationship of formally designated roles such as chairperson and secretary, on the interaction patterns in small groups.

(3) The stability of person sequencing over time in groups needs to be studied from the same kind of data obtained in (1) above.

It is particularly important that the research go beyond small groups in students in temporary groups. The existing data seems to show that person-to-person sequencing does not occur in such groups. The Watergate transcripts indicate that such sequencing

does occur in at least one real situation. Therefore, the research should concentrate on in vivo group functioning.

A rather large body of data is available on component state models of communication systems. Stech (1975a) has performed a review of the existing research in which distributional and sequential structure of human social interaction could be calculated from published or available data. The review included studies of discussion groups (Bales, 1966; Scheidel and Crowell, 1964; Fisher, 1970; Stech, 1970; and Gouran and Baird, 1972), classroom interaction (Lohman, et. al., 1967 and Pankratz, 1967), speech therapy situations (Boone and Goldberg, 1969), and police-civilian telephone conversations (Stech, 1968). The findings showed that the distributional structure varied from 3.4 to 41.9 per cent while the sequential structure ranged from 3.8 to 29.8 per cent. Total structure from both sources varied from 7.2 percent in one discussion group study to a high of 58.1 per cent in one study of classroom interaction. Generally, higher distributional and sequential structure were found in the situations in which roles were well defined (speech clinician and client, teacher and student, police officer and caller) and where the interaction tended to be dyadic rather than multi-person. Of the data examined, the data tended to show that sequences of acts in four distinctly different kinds of social situations were fairly highly constrained. The mean distributional structure was 19.7, the median 18.8 per cent. Mean sequential structure was 15.1 per cent with a median value of 14.0 per cent.

It is necessary to understand the possible range of relative distributional and sequential values in order to interpret the foregoing findings. Relative distributional structure can vary from 0 to 100 per cent while relative sequential structure can vary from 0 to 50 per cent, that is, the maximum possible structure due to sequencing constraint is 50 per cent in the case of zero distributional structure. Thus, the social communication situations covered in the review showed relatively high distributional and sequential structure on the average. The average total constraint from both sources was about one-third of the maximun possible.

These findings support the following proposition about what-follows-what in human social communication systems:

> Proposition 3: Message units in human social communication are not sequenced randomly.
>
> Proposition 3.1: Some kinds of message units occur more frequently than others in a wide variety of different communication situations. (Distributional constraint.)

Proposition 3.2: Some kinds of message units occur consistently after some kinds of message units and not after others. (Sequential structure.)

These propositions seem to hold for all the systems studied to date. The amount of constraint varies from rather low to quite high, but no systems were found in which there was no constraint at all. The average structure, both distributional and sequential, was reasonably high.

In addition to these two propositions, there is some data available on the degree to which human communication systems can be characterized as in an equilibrium process or not. The phase studies in small groups (Bales, 1950; Fisher, 1970) indicate that the interaction in such systems cannot be represented in the form of a Markov chain. I have taken Bales matrix of reactive tendencies in groups (Bales, 1966) and performed matrix multiplication on the transitional probabilities. When raised to about the 8th power, the matrix showed an equilibrium process which was different from the original matrix. A preliminary analysis showed that the resulting equilibrium probabilities were more similar to the distributions Bales found for highly satisfied groups and high interaction groups than for average groups or for groups which were dissatisfied or exhibited low interaction rates. This tends to support the notion that group discussion is not an equilibrium process.

I am in the process of extending these analyses to other sets of data on transition probabilities in small group discussion and for other social situations such as the classroom interactions, speech therapy sessions, and police-civilian telephone calls noted in the paragraph on distributional and sequential structure.

There is one piece of information (Hawes and Foley, 1973) which tends to indicate that at least one kind of interaction, that of the medical doctor interviewing a patient, is stable and can be represented as a Markov chain. The data show that predictions made from early portions of the interview process hold up for later segments and for the interview as a whole. Thus, at least one example of an interaction process in a state of equilibrium has been shown to exist.

The third subproposition in this series deals with the equilibrium process of human social communication systems.

Proposition 3.3: Interaction sequences early in the history of a communication system probably do not (but may) represent the equilibrium process for the system. (Phase structure.)

Much more additional work is needed in the analysis of existing

data and much more interaction data from a wide variety of social systems needs to be analyzed before the occurrence of stable processes can be specified with more accuracy and confidence.

In simple language, these findings suggest that it is fairly easy to predict what will be said next in social discourse. In the absence of any other prior information, the best bet is the most frequently occurring kind of message unit. If there is information available on what has happened, that is, context is taken into account, the best bet is the kind of unit which typically follows the immediately preceding unit. However, the kind of unit which occurs most frequently or the sequencing rules may change over the course of time so that it is necessary to know when in a system's history the predictions are to be made.

Additional research is needed along several fronts in this facet of the study of communication systems, some of which I have initiated in my most recent work:

(1) We need to examine the effect of context more closely to find out if there is additional constraint provided in three-unit, four-unit, and still larger sequences. To this point we have examined only the zero-order and first-order constraint in interaction sequences.

(2) The rules for sequencing in social interaction should be studied with particular attention to the syntactical rules which specify the generation of sequences of acts among individuals. The effect of task logic, number of interactants, and role specification needs to be examined in this context.

(3) Finally, more work is needed to assess the degree to which various kinds of communication systems are stable over time. Again, task effects, social roles, and system size may affect the existence of an equilibrium process.

The tools for these studies are at hand. We only need to do them.

The outlook in the final form of model to be considered here is much more gloomy. There is no published data, to my knowledge, which deals with the occurrence of different component states at the same time in face-to-face or geographically disperse systems. It seems trite and obvious to say that all the members of a group probably are not listening while another person is speaking. Some probably are listening, some are preparing to speak, some are glancing at one another, and yet others are daydreaming or other-

wise preoccupied. This kind of data is hard to acquire for at least two reasons. First, some of the needed information is fairly subjective, or at least we would have to rely on subjective reports in our current state of the art in observation. Second, the observation process would require either a lot of observers (one for each unit in the system, at least) or sophisticated recording techniques which would allow subsequent slow-time observation (such as one camera for each unit in the system with time synchronization for all the recording cameras.

As a result of the complete lack of data, it is not possible to spell out propositions on component state structural models. Based on our previous findings on the component structural model, the component state process model, and the component process model, it seems likely that the component state structural model will exhibit some amount of structure, but this is pure speculation at this time.

To recapitulate the need for further research, the what-is-going-on-while-something-is-being-said and the who-speaks-after-whom models have almost no empirical data for analysis. We have, as a discipline, tended to focus our attention on the source, sender, or emitter of messages in communication systems, a natural inclination in view of the evolution from the public speaking perspective. The end result of this focus has been to ignore what is happening to or being done by the other people in the communication situation. Yet casual observation of meetings, classrooms, and conventions, shows that the receivers are in varied states and may, in fact, be sending messages nonverbally to one another while someone else is talking. We have tended to assume that audiences and groups are listening. That assumption needs to be tested with empirical research.

Similarly, our research focus in terms of process has been on the transition from one kind of message to another or from one mode of operation to another in discussion groups. The studies of sequences of acts or of cycles or phases in discussion concentrate on the messages being sent. Yet there may be important information about communication systems in terms of who sends the next message or who consistently sends messages after another person. Very little research data is available on this question.

The possibility of interaction between two kinds of models must also be taken into account. There is structure in terms of who talks to whom in most social systems. There is also structure in terms of what is said next. I have considered the two models, one structural and the other process, separately. There is some evidence that who-speaks-next may be patterned in some situations. Very little evidence is available on what is happening in other components while one component is sending. Yet it seems entirely reasonable to assume that the four views of the communication

system overlap and interrelate. For example, there seems to be evidence that who-talks-to-whom and who-talks-after-whom are predictable features of some communication systems. There is data (Bales, 1955) to indicate that certain components typically say specific kinds of things more frequently than other components. There is evidence that what-is-said-next is predictable. Therefore, there must be links between who is talking and what is being said, who will talk next, what will be said next, and what the person who talks next will say. Unfortunately, we are not yet at the point in the empirical analysis of most communication systems to make these kinds of interactive predictions. The possibility, however, is clear and does not appear to be out sight.

In summary, the research literature showed that two kinds of models are used most commonly as the underlying basis for empirical studies; the component structural model (who communicates with whom) and the component state process model (what is said after what). Matrix methods, Markov chain techniques, uncertainty statistics, and graph theory methods have been employed sporadically and sparingly to the analysis of communication system data. No published research could be found which attempted to analyze component sequences (who speaks after whom) or component state structural networks (what is going on while something is being said).

Communication systems are organized or structured in at least three different senses: as networks of components, as sequences of components and as sequences of component states. The degree of organization can be calculated and a program for the computation of these values from published data has been initiated. In addition, procedures for assessing system stability have been applied in a few cases. The ultimate result of these efforts, it is hoped, will be a better picture of the ways in which communication systems are organized and the degree to which they represent nonrandom, predictable structures or processes.

A 26

REFERENCES

Amidon, E. J. and J. B. Hough. (Eds.) Interaction Analysis: Theory Research, and Application. Reading, Mass.: Addison-Wesley, 1967.

Berlo, David K. The Process of Communication. New York: Holt, Rinehart, and Winston, 1963.

Bales, R. F. Interaction Process Analysis. Reading Mass.: Addison-Wesley, 1950.

Bales R. F. "The Equilibrium Problem in Small Groups." In A. P. Hare et. al., (Eds.), Small Groups: Studies in Social Interaction. New York: Knopf, 1966.

Bales, R. F. and F. L. Strodtbeck. "Phases in Group Problem-Solving." Journal of Abnormal and Social Psychology, 1951, 46, 485-495.

Bales, Robert F., Fred L. Strodtbeck, Theordore M. Mills, and Mary E. Roseborough. "Channels of Communication in Small Groups," American Sociological Review, 1951, 16, 461-468.

Bales, R. F. Some Uniformities of Behavior in Small Social Systems. In P. F. Lazarsfeld and M. Rosenberg (Eds.), The Language of Social Research. Glencoe, Illinois: The Free Press, 1955.

Bartos, Otomar J. Simple Models of Group Behavior. New York: Columbia University Press, 1967.

Bavelas, Alex "A Mathematical Model for Group Structures," Applied Anthropology, 1948, 7, 16-30.

Behzad, Mehdi and Gary Chartrand. Introduction to the Theory of Graphs. Boston: Allyn & Bacon, 1971.

Boone, D. R. and A. Goldberg. An Experimental Study of the Clinical Acquisition of Behavioral Principles by Videotape Self-Confrontation. Final report to the U. S. Department of Health, Education, and Welfare, Grant No. OEG-8-071319-2814. Denver, Colorado: University of Denver, 1969.

Burke, Peter R. Participation and Leadership in Small Groups. American Sociological Review, 1974, 39, 832-843.

Chapple, Eliot D. Quantitative Analysis of the Interaction of Individuals. Proceedings of the National Academy of Sciences, 1939, 25, 58-67.

A 27

Chapple, Eliot D. and Arensberg, Conrad M. "Measuring Human Relations: An Introduction to the Study of the Interaction of Individuals." Genetic Psychology Monographs, 1940, 22, 3-147.

Duncan, Starkey, Jr. "Some Signals and Rules for Taking Speaking Turns in Conversations." Journal of Personality and Social Psychology, 1972, 23, 283-292.

Festinger, Leon. "The Analysis of Sociograms Using Matrix Algebra." Human Relations, 1949, 2, 153-158.

Festinger, L., Stanley Shachter, and Kurt Back. "Matrix Analysis of Group Structures." In Paul F. Lazarsfeld and Morris Zelditch (Eds.), The Language of Social Research. Glencoe, Ill.: Free Press, 1955.

Fisher, B. A. "Decision Emergence: Phases in Group Decision Making." Speech Monographs, 1970, 37, 53-66.

Garner, W. R. Uncertainty and Structure as Psychological Concepts. New York: Wiley, 1962.

Gouran, D. S. and J. E. Baird, Jr. "An Analysis of Distributional and Sequential Structure in Problem-Solving and Informal Group Discussion." Speech Monographs, 1972, 39, 16-22.

Harary, Frank "Status and Contrastatus." Sociometry, 1959, 22, 23-43.

Harary, Frank and Ian C. Ross. "The Number of Complete Cycles in a Communication Network." Journal of Social Psychology, 1954, 40, 329-332.

Harary, Frank and Ian C. Ross. "A Procedure for Clique Detection Using the Group Matrix." Sociometry, 1957, 20, 205-215.

Hawes, Leonard C. and Joseph M. Foley "A Markov Analysis of Interview Communication." Speech Monographs, 1973, 40, 208-219.

Jaffe, Joseph and Stanley Feldstein. Rhythms of Dialogue. New York: Academic Press, 1970.

Karlsson, Georg. "Note on the Spread of a State in Small Social Groups." Bulletin of Mathematical Biophysics, 1955, 17, 1-5.

A 28

Leeman, Calvin P. "Patterns of Sociometric Choice in Small Groups: A Mathematical Model and Related Experimentation." Sociometry, 1952, 15, 220-243.

Lohman, E. E., R. Ober, and J. B. Hough. "A Study of the Effect of Pre-Service Training in Interaction Analysis on the Verbal Behavior of Student Teachers." In E. J. Amidon and J. B. Hough, (Eds.), Interaction Analysis: Theory, Research, and Application. Reading, Mass.: Addison-Wesley, 1967.

Moreno, J. L. "Foundations of Sociometry, an Introduction." Sociometry, 1941, 4, 15-35.

Pankratz, R. "Verbal Interaction Patterns in the Classrooms of Selected Physics Teachers." In E. J. Amidon and J. B. Hough, (Eds.), Interaction Analysis: Theory, Research, and Application. Reading, Mass.: Addison-Wesley, 1967.

Rapoport, Anatol and Lionel I. Rebhun. "On the Mathematical Theory of Rumor Spread." Bulletin of Mathematical Biophysics, 1952, 14, 375-383.

Ross, Ian C. and Frank Harary. "Identification of the Liaison Persons of an Organization Using the Structure Matrix." Management Sciences, 1955, 1, 251-258.

Ross, Ian C. and Frank Harary. "A Description of Strengthening and Weakening Members of a Group." Sociometry, 1959, 22, 139-147.

Scheidel, T. M. and L. Crowell. "Idea Development in Small Discussion Groups." Quarterly Journal of Speech, 1964, 50, 140-145.

Shannon, C. E. and W. Weaver. The Mathematical Thoery of Communication. Urbana, Ill.: University of Illinois Press, 1949.

Stech, E. L. "Pattern and Structure in Role Enactment: A Quantitative Study." Paper presented at the Annual Meeting of the Rocky Mountain Social Sciences Associateion, Lubbock, Texas, May 1968.

Stech, E. L. "An Analysis of Interaction Structure in the Discussion of a Ranking Task." Speech Monographs, 1970, 37, 249-256.

Stech, E. L. "An Analysis of the Interaction Between Speech Therapists and Clients." Unpublished manuscript, Western Michigan University, Kalamazoo, Michigan, 1973.

Stech, Ernest L. "A Preliminary Empirical Comparison of the Interact System and the Human System Models of Group Interaction." Unpublished manuscript. Western Michigan University, Kalamazoo, Michigan, 1974.

Stech, Ernest L. "Sequential Structure in Human Social Communication." In press. Human Communication Research, 1, 1975a

Stech, Ernest L. "A Method for the Measurement of Degree of Organization in Social Systems." To be presented at the Annual Convention of the International Communication Association, April 1975b.

Stinchcombe, Arthur L. "On the Use of Matrix Algebra in the Analysis of Formal Organizations." In Amitai Etzioni (Ed.), Complex Organizations: A Sociological Reader, New York: Holt, Rinehart, Winston, 1961.

Weick, Karl E. "Middle Range Theories of Social Systems." Behavioral Science, 1974, 19, 357-367.

Weiss, Robert S. and Eugene Jacobson. "A Method for the Analysis of the Structure on Complex Organizations." In Amitai Etzioni (Ed.) Complex Organizations: A Sociological Reader, New York: Holt, Rinehart, Winston, 1961.

		UNIT B		
		PASSIVE	ACTIVE	
			Sending	Receiving
UNIT A	PASSIVE	no system	no system	no system
	ACTIVE			
	Sending	no system	mutual send	send receive
	Receiving	no system	send receive	mutual receive

Figure 1

Possible States of Two
System Components

		UNIT B	
		SEND	RECEIVE
UNIT A	SEND	babble	communication
	RECEIVE	communication	silence

Figure 2

Possible States of a Two Component System in Face to Face Interaction

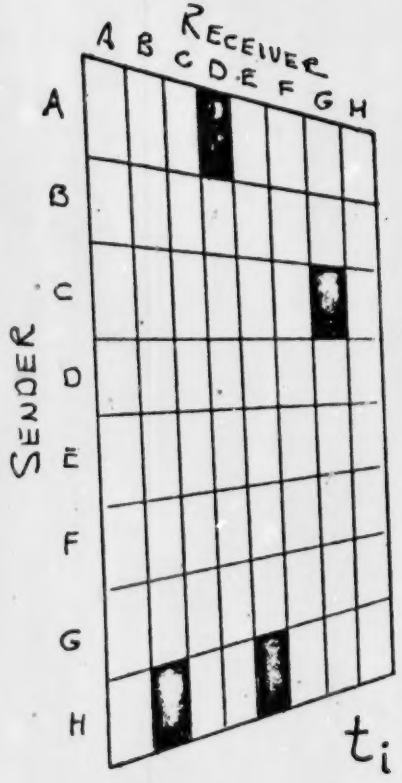

Figure 3

A System State Matrix
for One Point in Time

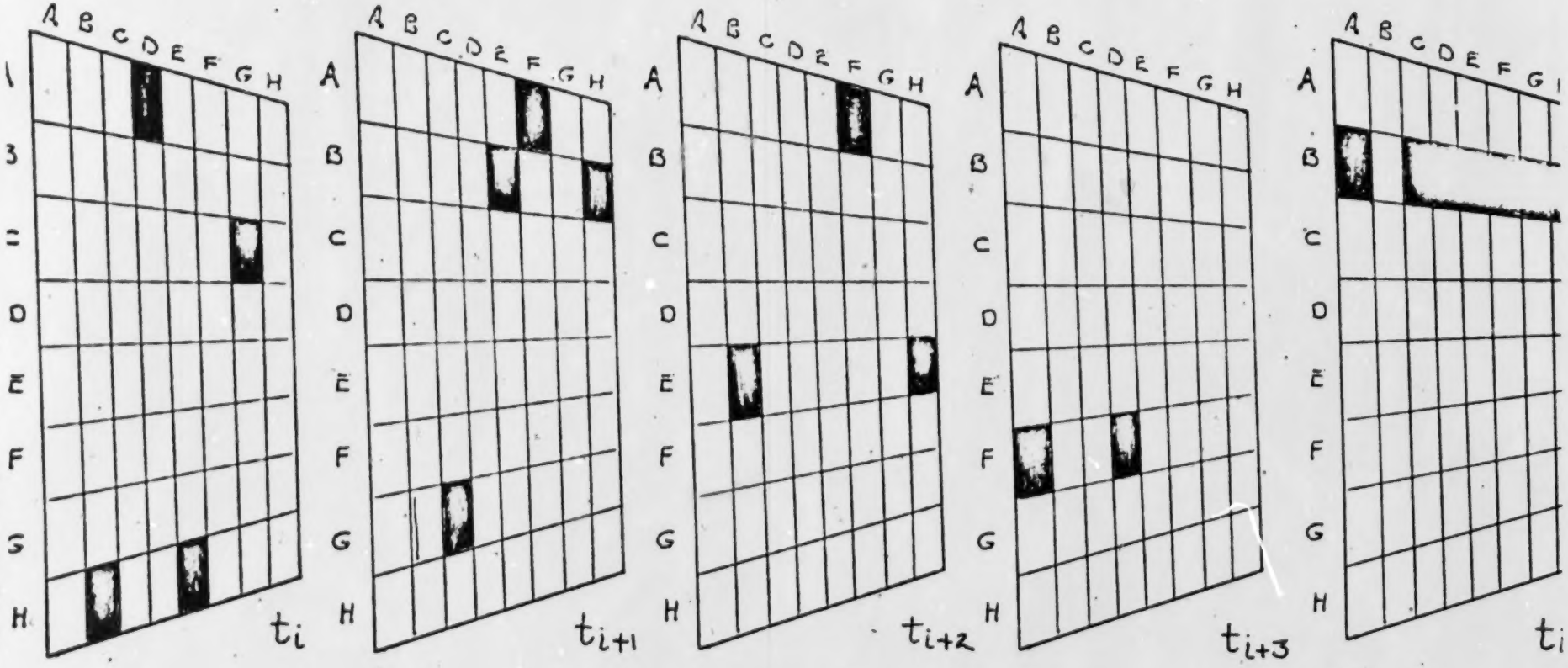

Figure 4

A Series of System State Matrices
for Five Points in Time

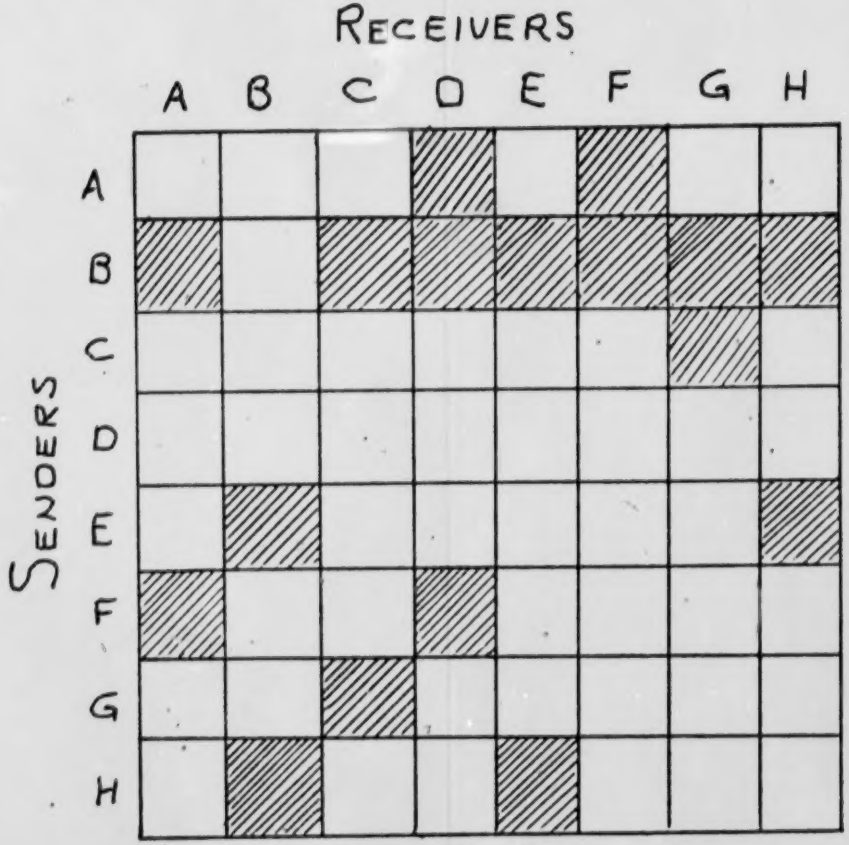

Figure 5

A Summed System State Matrix
Showing Who-Spoke-to-Whom

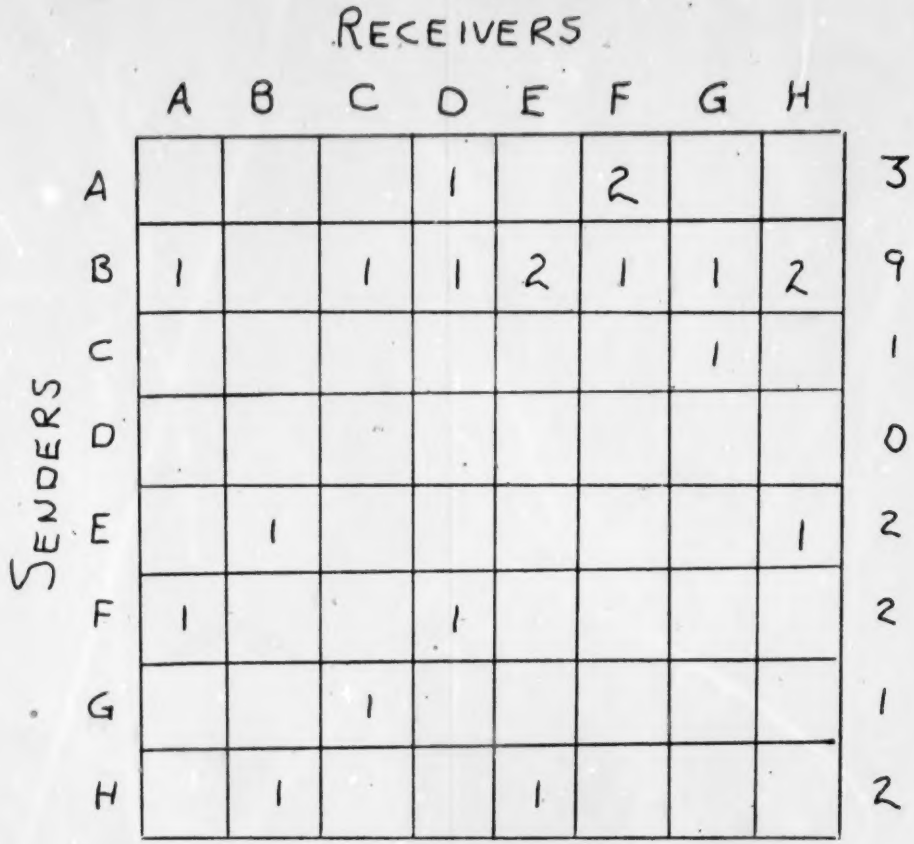

Figure 6

A Summed System State Matrix Showing
the Frequency of Who-Spoke-toWhom

	A	B	C	D	E	F	G	H	
A		1		1		3			5
B	1		1	1	3	1	1	3	11
C		1					2		3
D	1	1				1			3
E		3						2	5
F	3	1		1					4
G		1	2						3
H		3			2				5
	5	11	3	3	5	4	3	5	40

Figure 7

A Summed System State Matrix Showing
the Frequency of Linkages Between
Components Without Regard to Direction of Communication

A 36

A 37

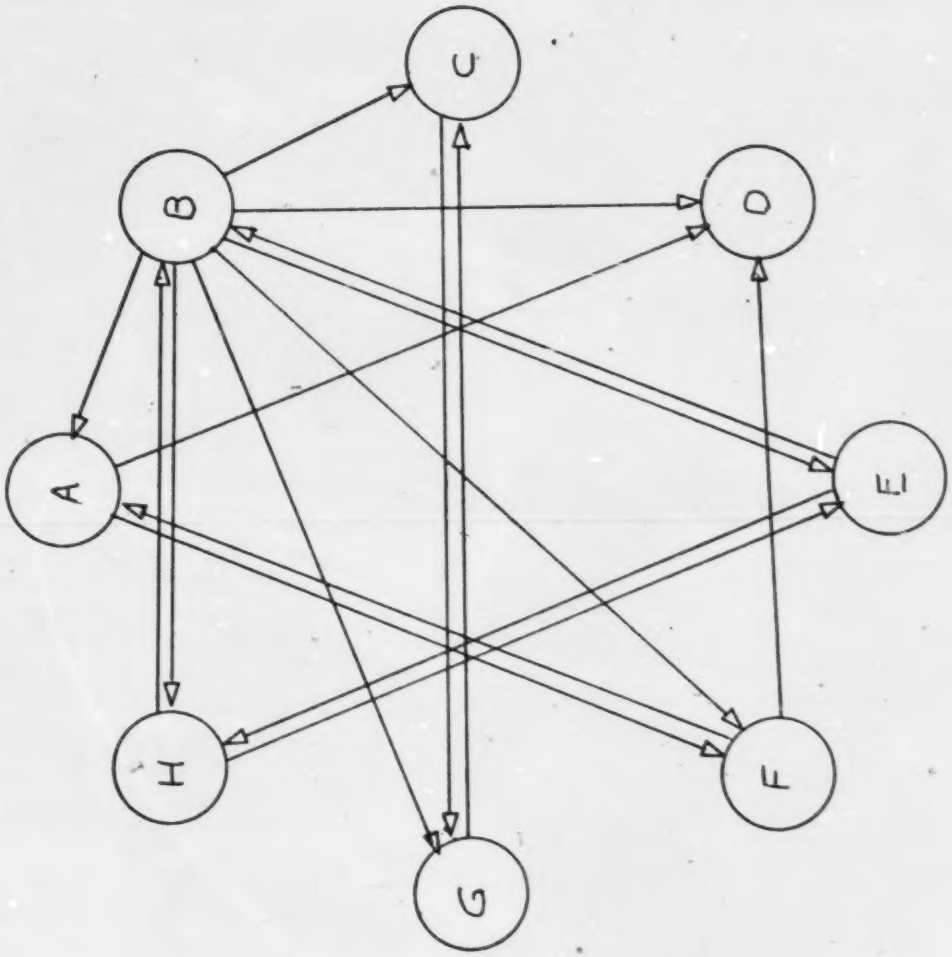

Figure 8

A Network Diagram Showing
Who-Spoke-toWhom

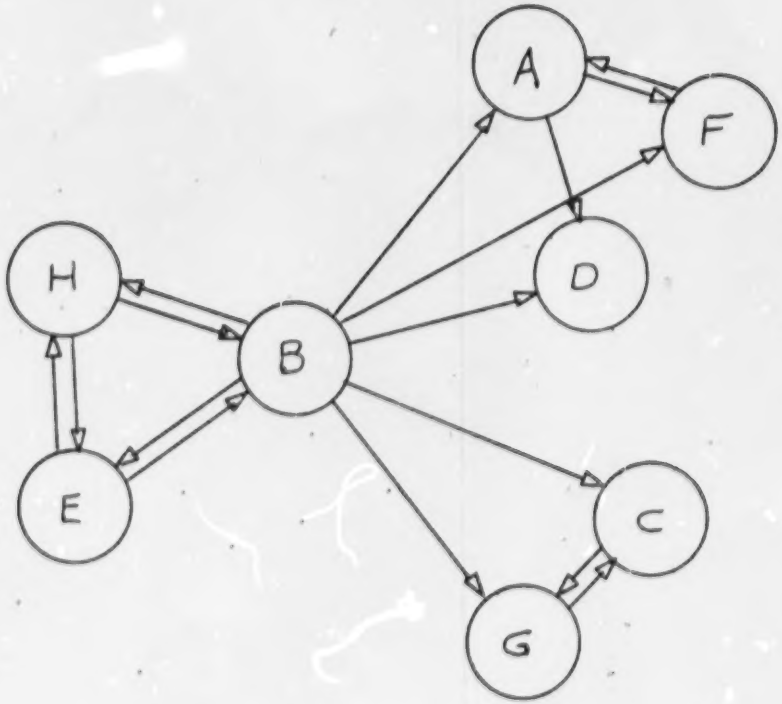

Figure 9

A Network Diagram Redrawn to Highlight
Groupings of Who-Spoke-to-Whom

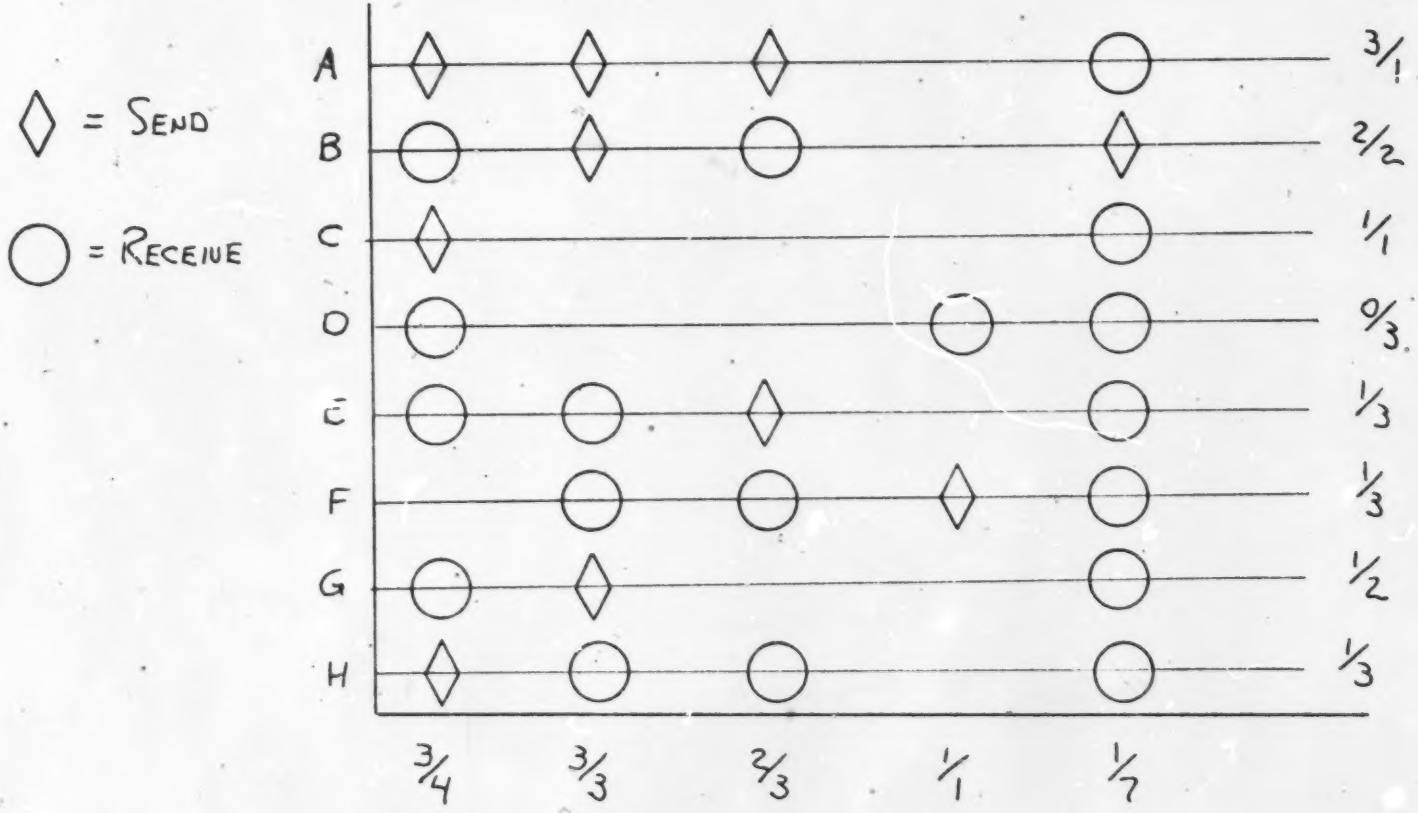

Figure 10

A Summary Time Line Chart
of Component States

	SEND	RECEIVE	PASSIVE	
SEND	2	3	4	9
RECEIVE	4	4	3	11
PASSIVE	1	7	4	12
	7	14	11	32

Figure 11

A Matrix Showing the Frequency of Occurrence of Component State Changes

	SEND	RECEIVE	PASSIVE	
SEND	.06	.09	.13	.28
RECEIVE	.13	.13	.09	.35
PASSIVE	.03	.21	.13	.37
	.22	.43	.35	1.00

Figure 12

A Relative Frequency of Occurrence Matrix
of Component State Changes

	SEND	RECEIVE	PASSIVE	
SEND	.22	.33	.45	1.00
RECEIVE	.36	.36	.28	1.00
PASSIVE	.08	.59	.33	1.00

Figure 13

A Transition Probability Matrix of
Component State Changes

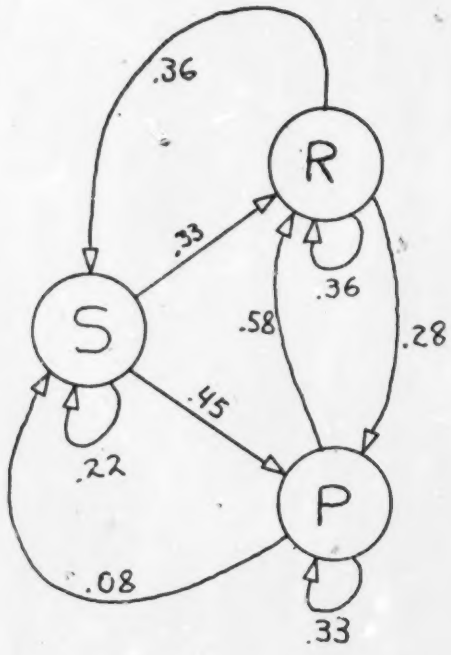

Figure 14

A State Change Diagram

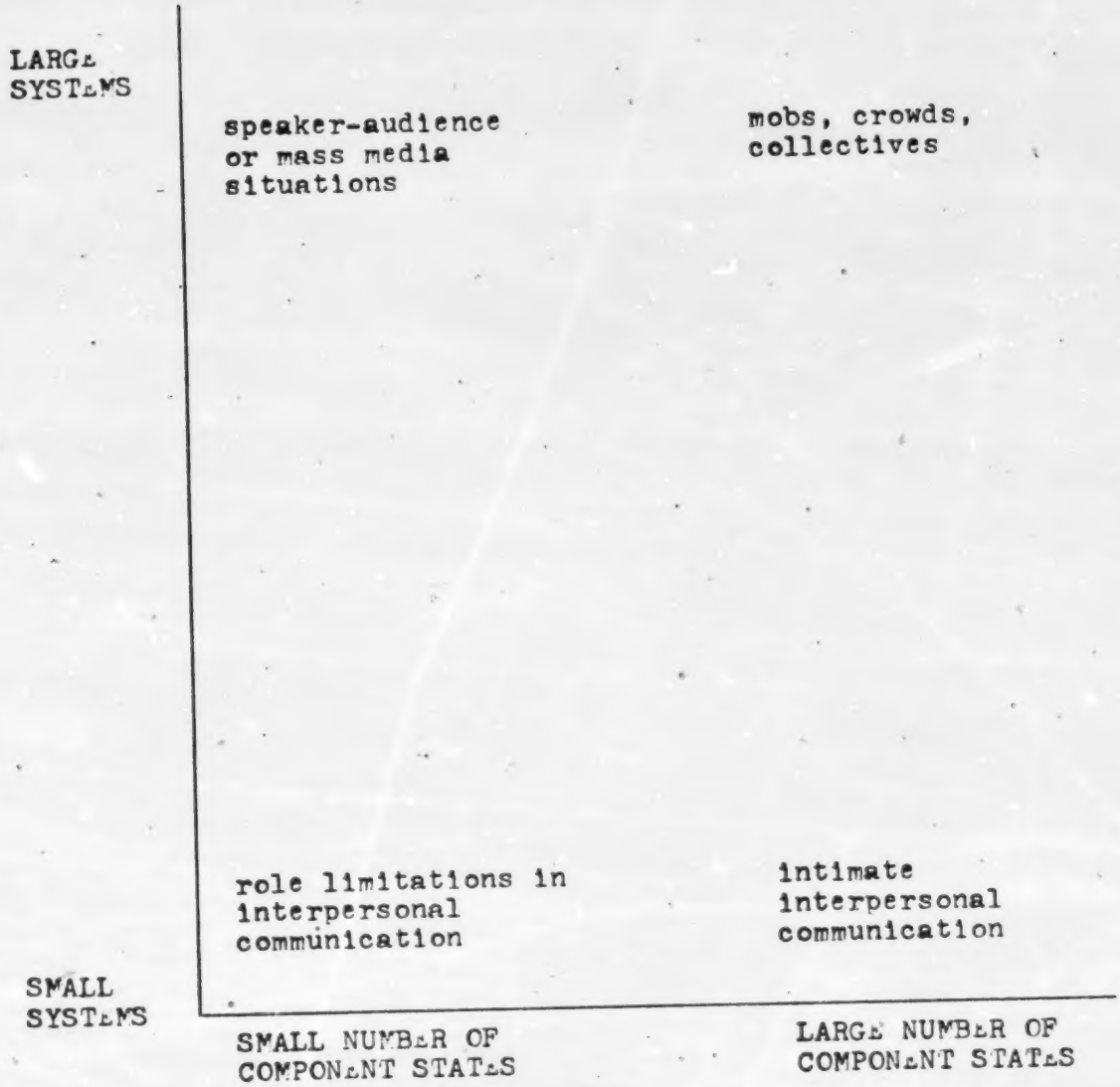

Figure 15

Taxonomy Based on System Size and Number of Component States

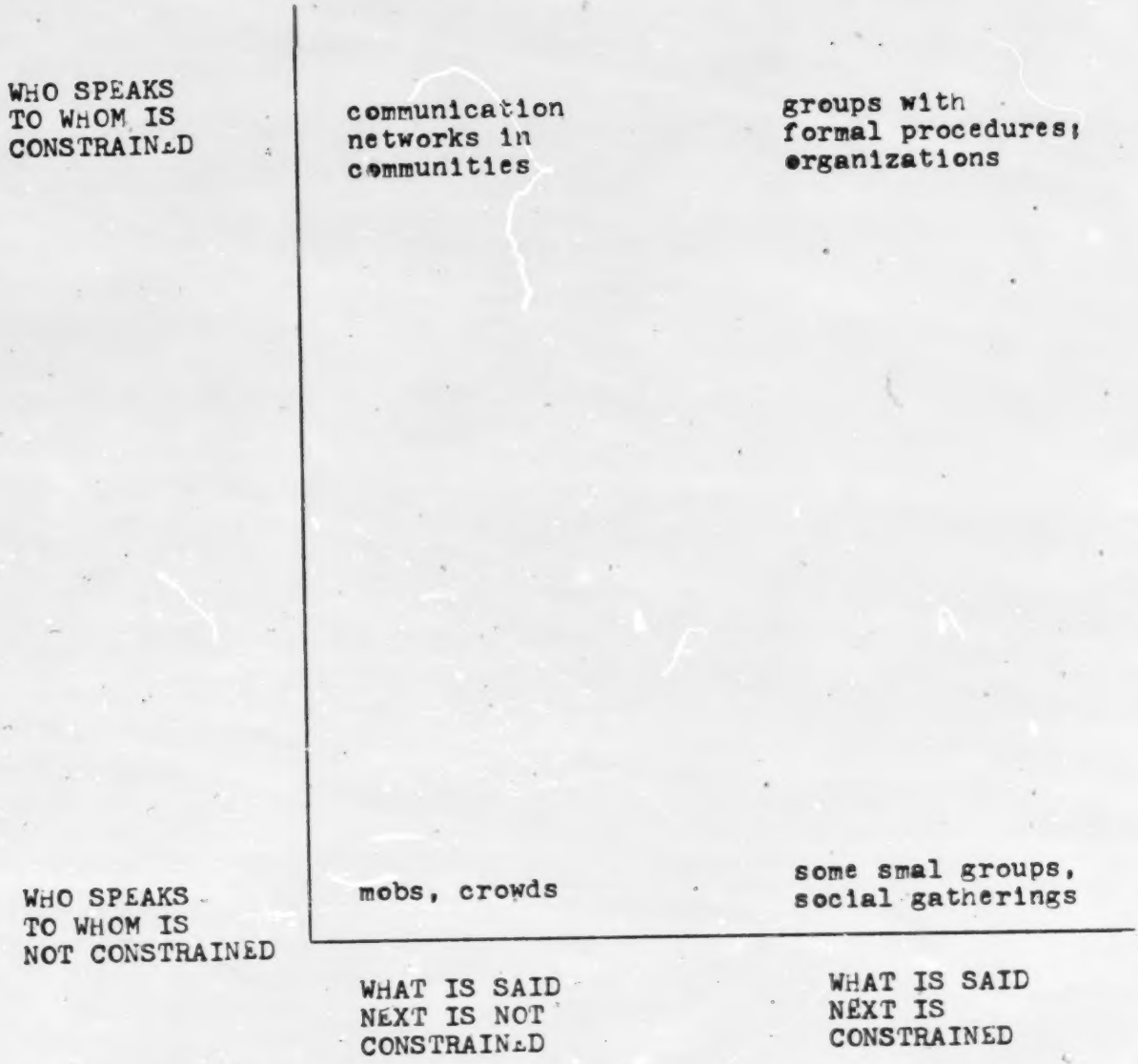
WHO SPEAKS TO WHOM IS CONSTRAINED
communication networks in communities
groups with formal procedures; organizations
WHO SPEAKS TO WHOM IS NOT CONSTRAINED
mobs, crowds
some smal groups, social gatherings
WHAT IS SAID NEXT IS NOT CONSTRAINED
WHAT IS SAID NEXT IS CONSTRAINED

Figure 16

Taxonomy Based on Degree of Constraint on Who Speaks Next and What is Said Next